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SPACE SHUTTLE
AEROTHERMODYNAMIC DATA REPORT

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(NASA-CR-151395) AERONOISE TEST RESULTS
USING A 0.040-SCALE SHUTTLE VEHICLE
CONFIGURATION 2A MODEL (11-OTS) IN THE AMES
RESEARCH CENTER UNITARY PLAN WIND TUNNELS
(TS1A/B/C AND OS3) (Chrysler Corp.) 46 p

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by

B. J. Herrera
Shuttle Aero Sciences
Rockwell International Space Division

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by

Data Management Services
Chrysler Corporation Michoud Defense-Space Division
New Orleans, La. 70189

for

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WIND TUNNEL TEST SPECIFICS:

Test Number:	ARC 705-1-11/97/87
NASA Series Number:	IS1A/B/C and OS3
Model Number:	11-OTS
Test Dates:	July 23, 1973 through August 12, 1973
Occupancy Hours:	150

FACILITY COORDINATOR:

J. J. Brownson
Mail Stop 227-5
Ames Research Center
Moffett Field, CA. 94035

Phone: (415) 965-6262

PROJECT ENGINEERS:

B. J. Herrera
Mail Code AD38
Rockwell International
Space Division
12214 Lakewood Blvd.
Downey, CA. 90241

Phone: (213) 922-4939

C. L. Stevens
Mail Code AB97
Rockwell International
Space Division
12214 Lakewood Blvd.
Downey, CA. 90241

Phone: (213) 922-4677

R. E. Fahey
J. B. Dods
R. D. Hanly
Ames Research Center
Moffett Field, CA. 94035

Phone: (415) 965-6348

DATA MANAGEMENT SERVICES:

Prepared by: Liaison--D. W. Hersey
Operations--Maurice Moser, Jr.

Reviewed by: G. G. McDonald

Approved: J. L. Glynn
J. L. Glynn, Manager
Data Operations

Concurrence: N. D. Kemp
N. D. Kemp, Manager
Data Management Services

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AERONOISE TEST RESULTS USING A 0.040-SCALE SPACE SHUTTLE VEHICLE CONFIGURATION 2A MODEL (11-OTS) IN THE AMES RESEARCH CENTER UNITARY PLAN WIND TUNNELS (IS1A/B/C AND OS3)

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B. J. Herrera, Rockwell International

ABSTRACT

Fluctuating pressure (aeronoise) distributions on the space shuttle launch vehicle and orbiter were obtained in the Ames Research Center Unitary Plan Wind Tunnels. These tests were conducted at Mach numbers ranging from 0.6 to 3.5 for the first stage launch configuration and at Mach numbers from 2.5 to 3.5 for the entry configuration. Tabulated data are not available for this report.

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NOMENCLATURE

SYMBOL	DEFINITION
a	speed of sound; m/sec, ft/sec
C_i	Beckman counts of the calibration reading (0.500 volt RMS)
C_p	pressure coefficient; $(p_1 - p_\infty)/q$
$C_{p_{RMS_i}}$	RMS pressure coefficient
dB_{flt_i}	flight dB level
dB_{tun_i}	tunnel dB level
g_i	Beckman counts of the gain reading
G_i	amplifier gain for channel i
K_{2i}	RMS-Beckman count calibration factor
K_T	transducer sensitivity
M_∞	Mach number; V/a
p	pressure; N/m^2, psf
p'_i	flight RMS pressure
q_∞	dynamic pressure; $1/2\rho V^2$, N/m^2, psf
q_{FLT}	flight dynamic pressure, psf
R_i	RMS Beckman counts
RN/L	unit Reynolds number; per m, per ft
V	velocity; m/sec, ft/sec
X_i	first digit of g_i
α	angle of attack, degrees
P_t	tunnel stagnation pressure, in. H_g

NOMENCLATURE (Concluded)

SYMBOL	DEFINITION
β	angle of sideslip, degrees
ρ	mass density; kg/m^3, $slugs/ft^3$
RMS	root mean square
ϕ	radial location of orifice, 0° at bottom CL looking aft
X	longitudinal station
Y	lateral station
Z	vertical station

SUBSCRIPTS

o	orbiter
T	external tank
s	solid rocket booster

INTRODUCTION

This report presents test information for aeronoise tests IS1A/B/C and OS3 conducted in the NASA Ames Research Center Unitary Plan Wind Tunnels (UPWT). The purpose of these tests was to measure the fluctuating pressure (aeronoise) environment of the space shuttle launch vehicle during transonic and supersonic phases of ascent (IS1A/B/C) and of the orbiter during the supersonic phase of entry (OS3). The model used in these tests was a 0.04-scale replica of the space shuttle launch vehicle designated 11-OTS. This model was instrumented with dynamic pressure transducers (microphones) to obtain the fluctuating component of the surface pressure.

CONFIGURATIONS INVESTIGATED

The model used for tests IS1A/B/C and OS3 was an 0.040-scale space shuttle integrated vehicle model designated 11-OTS. The model consisted of the orbiter, external tank and two solid rocket boosters designed to the baseline 2A mold lines with modifications as given in Table III. The forward and aft orbiter - ET attach structures were simulated. The elevons and rudder were fixed at 0° deflection; the body flap had the capability of 0 and +10° deflection.

General arrangement for the orbiter and the integrated vehicle is shown on Figures 1a and 1b. All model components were fabricated from aluminum alloy except the main and secondary sting which were stainless steel. All components were designed for a load-safety factor of five bases on ultimate strength and three based on yield strength.

Model nomenclature is as follows:

Component	Definition
B_{18}	Modified 2A fuselage body. Manipulator housing has been removed from the baseline 2A fuselage lines drawing VL70-000093.
C_8	Modified 2A canopy. Manipulator housing fairing has been removed from the baseline 2A canopy lines drawing VL70-000094.
F_4	Baseline body flap per lines drawing VL70-000094.
M_5	Modified orbital maneuvering subsystem (OMS) pods. Slight modifications to aft face were made for ease of construction; otherwise, baseline 2A lines (VL70-000094) were followed.
V_7	Vertical tail per lines VL70-000139.

CONFIGURATIONS INVESTIGATED (Concluded)

Component	Definition
W_{108}	Modified 2A wing. Planform and dihedral per lines VL70-000093.
S_6	Solid rocket booster (SRB) per lines VL77-000012 and VL72-000061B.
T_{10}	External tank (ET) per lines VL78-000041.

Dimensional data for model 11-OTS are given on Table III.

Configurations tested:

Configuration	Components
Orbiter	B_{18} C_8 F_4 M_5 V_7 W_{108}
Launch Vehicle 1	Orbiter T_{10} S_6
Launch Vehicle 2	Orbiter T_{10} S_6 (S_6 W/shortened SRB skirt)

INSTRUMENTATION

The model was instrumented with 87 Kulite pressure transducers. All transducers were installed in holders and each one had a line driver to eliminate signal losses due to cable length to the data system. Transducer reference lines were manifolded together inside the model and vented to the tunnel support strut structure.

The number of transducers in each model component was as follows:

Orbiter	55
External Tank	20
Left SRB	12

The orbiter transducers were located on the nose, fuselage top, bottom and sides, OMS pod, vertical tail, and wing upper and lower surfaces. Locations are shown on Figures 2a and 2b and given in Table IV.

The external tank transducers were located on the left side of the tank at various longitudinal and angular locations. Locations are shown on Figure 2c and given in Table V.

The left SRB transducers were located on the right side of the SRB at various longitudinal and angular locations. Locations are shown on Figure 2d and given in Table VI.

The Kulite transducers used in this test were model number XCQL-7A-093-4. This model is rated at 4 psi and it is not temperature compensated. Sensitivity is 150 - 250 millivolt full scale at 30 volts DC excitation.

The model was also instrumented with an ARC pendulum angle sensor to indicate angle of attack in the 11 x 11 and 8 x 7 tunnels and yaw angle in the 9 x 7 tunnel and a biaxial accelerometer to monitor vibrations.

TEST FACILITIES DESCRIPTION

Ames 11 x 11-Foot Transonic

The Ames 11 x 11-Foot Transonic Wind Tunnel is a variable density, closed return, continuous flow type. This tunnel has an adjustable nozzle (two flexible walls) and a slotted test section to permit transonic testing over a Mach number range continuously variable from 0.4 to 1.4.

Ames 8 x 7-Foot Supersonic

The Ames 8 x 7-Foot Supersonic Wind Tunnel is a closed-return, variable-density tunnel with a 8- by 7-foot rectangular test section. The nozzle has flexible side walls with fixed upper and lower surfaces. Mach number range is continuously variable from 2.45 to 3.5. Tunnel stagnation pressure can be varied from 0.3 to 2.0 atmospheres and Reynolds number per foot varies from 1.0×10^6 to 5.0×10^6.

Ames 9 x 7-Foot Supersonic

The Ames 9 x 7-Foot Supersonic Wind Tunnel is a variable density, continuous flow type with an adjustable nozzle to permit supersonic testing over a Mach number range continuously variable from 1.5 to 2.5. The nozzle is of the asymmetric, sliding-block type in which the variation of the test section Mach number is achieved by translating in the streamwise direction the fixed-contour block that forms the floor of the nozzle.

TEST PROCEDURE

Installation

Model 11-OTS was sting mounted through its base. The primary sting supported the orbiter and the secondary sting supported the ET/SRB assembly. Each SRB was attached to the ET at two points. The forward ET attach structure was used to maintain the relative positions of the orbiter and ET. Installation photographs are shown in Figures 3a through 3d.

The instrumentation leads were routed through the base of the orbiter and ET and wrapped around the sting. The leads were covered with tape and fiberglass for protection. The model leads terminated at the base of the strut pod where terminal strips were available to connect to the facility data lines from the control room.

Calibrations

Each pressure transducer was calibrated prior to installation in the model and after hookup to the data system. The calibration range was ± 1.0 psi. The transducer excitation voltage was adjusted to produce an output voltage of 50 mv/psi.

Operations

Data were recorded during two distinct modes of operation: one was the discrete point and the other was the Mach sweep. The discrete point mode was used on all three test facilities and the Mach sweep mode was used in the 11 x 11 ft. tunnel only.

The discrete point mode operating sequence was to set up the desired model attitude and tunnel conditions and then record the data. The data recording consisted of two cycles. The first cycle was to record the tunnel conditions and amplifier gains; the second cycle was to record the tunnel conditions and the RMS data. The aeronoise data were also tape recorded during the second cycle.

The Mach sweep mode operating sequence was to set up the desired model attitude and initial tunnel conditions and to record the tunnel conditions and amplifier gains. After the presweep data were recorded, the Mach number was slowly but steadily increased over a 15 minute time period to the tunnel maximum Mach number. During this time period, tunnel conditions and RMS data were recorded every 15 seconds and the aeronoise data were continuously tape recorded. After the above recordings were completed, the tunnel conditions and amplifier gains were recorded.

DATA REDUCTION

The data system used during tests IS1A/B/C and OS3 consisted of transducer power supplies, amplifiers, tape recorders, RMS voltmeters, and the facility Beckman system. The power supplies provided variable DC power for the transducers and line drivers. One power supply per transducer was used. The amplifiers used were variable gain DC and AC coupled amplifiers, most of which had automatic gain controls. The amplified signal was recorded on three 32 channel magnetic tape recorders for processing at the Dynamics Data lab at Space Division. Each reel of tape contained zero and calibration signals. The amplifier output was also connected to RMS meters. The output of the RMS meters was digitized by the facility Beckman system for further reduction. The Beckman system also recorded the amplifier gains and all the tunnel operating conditions. Tunnel operating conditions were computed using standard Ames equations.

The amplifier gains were calculated using the following equation:

$$G_i = 10^{\left(\frac{X_i - 2}{2}\right)}$$

where

G_i is the amplifier gain for channel i

X_i is the first digit of g_i

g_i is the Beckman counts of the gain reading

The RMS-Beckman count calibration factors were computed with the following equation:

$$K_{2i} = \frac{C_i}{0.500}$$

where

K_{2i} is the RMS-Beckman count calibration factor

C_i is the Beckman counts of the calibration reading (0.500 volts RMS)

The RMS pressure coefficient was calculated with the following equation:

$$C_{P_{RMS_i}} = \frac{144}{G_i \, q_\infty} \frac{R_i}{K_T \, K_{2i}}$$

where

$C_{P_{RMS_i}}$ is the RMS pressure coefficient

R_i is the RMS Beckman counts

K_T is the transducer sensitivity

q_∞ is the tunnel dynamic pressure

The tunnel dB level was calculated with the following equation:

$$dB_{tun_i} = 20 \log_{10} \left[\frac{p_i}{0.290 \times 10^{-8}}\right]$$

where

dB_{tun_i} is the tunnel dB level

p_i is the RMS pressure calculated from

$$p_i = \frac{CP_{RMS_i} \, q_\infty}{144}$$

The flight dB level is computed from the following equation:

$$dB_{flt_i} = 20 \log_{10} \left[\frac{p'_i}{0.290 \times 10^{-8}}\right]$$

where

dB_{flt_i} is the flight dB level

p'_i is the flight RMS pressure calculated from

$$p'_i = \frac{CP_{RMS_i} \, q_{FLT}}{144}$$

q_{FLT} is obtained from Table VII "Flight Dynamic Pressure Lookup Table."

Tabulations of tunnel conditions and RMS data are available from the Rockwell International project engineers listed on p ii.

REFERENCE

1. SD 73-SH-0136, Rockwell Report, "Pretest Information for Tests of the 0.040-Scale Space Shuttle Vehicle Aerodynamic Noise Model 11-OTS in the Ames Research Center Unitary Plan Wind Tunnels," by B. J. Herrera, dated May 11, 1973.

TABLE I.

TEST : IS1A/B/C, OS3			DATE :
TEST CONDITIONS			
MACH NUMBER	REYNOLDS NUMBER (per foot)	DYNAMIC PRESSURE (pounds/sq.foot)	STAGNATION TEMPERATURE (degrees Fahrenheit)
0.6	2.88×10^6	344	78
0.7	3.21	440	80
0.8	3.46	521	80
0.9	3.63	592	82
1.0	3.78	662	85
1.1	3.91	736	91
1.2	2.34	451	84
1.3	2.32	462	84
1.6	3.85	894	107
2.0	3.42	759	120
2.2	3.15	672	115
2.5	2.76	543	107
3.0	2.08	364	117
3.5	1.62	239	112

BALANCE UTILIZED: NONE

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF			
SF			
AF			
PM			
RM			
YM			

COMMENTS:

TABLE II.

TEST: IS-1A | **TUNNEL:** 11x11

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES P_t, in Hg				NO. OF RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) A	B	.9	1.0	1.1					
	LAUNCH VEHICLE 2	1	0	25					8, 16		18/1515	19/1516	20/1517					
		-3	0						9									
		5	0						10		23/1520	22/1519	21/1518					
		9	0						11									
		-2	3						12									
		1	3						13									
		5	4						14, 17									
		1	6						15									
		1	0	15						24								
		5	0	15						25								

TEST RUN NUMBERS

TYPE OF DATA α OR β SCHEDULES — COEFFICIENT SCHEDULES — IDVAR (1) — IDVAR (2) — NDV

MACH SWEEP A : 0.6 → 1.1
MACH SWEEP B : 0.9 → 1.3

TABLE II. (Continued)

TEST: IS-1B | TUNNEL: 9x7

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES Pt, in Hg				NO. OF RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 1.6	2.0	2.2	2.5						
	LAUNCH VEHICLE 1	-3	0	30					3/120	2/113	4/126	1/102						
		1	0						3/121	2/116	4/127	1/105						
		5	0						3/122	2/115	4/128	1/106						
		-2	3						3/123	2/117	4/129	1/107						
		1	3						3/124	2/118	4/130	1/108						
		3	3						3/125	2/119	4/131	1/112						

TEST RUN NUMBERS

TYPE OF DATA — COEFFICIENT SCHEDULES — IDVAR (1) — IDVAR (2) — NDV

α OR β SCHEDULES

TABLE II. (Continued)

TEST: IS-1C | TUNNEL: 8X7

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES P_t, in Hg				NO. OF RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 2.5	3.0	3.5							
	LAUNCH VEHICLE 2	-3	0	30					26/1617									
		0	0						26/1618	27/1620	28/1623							
		1.8	0						26/1619									
		3.85	0							27/1621								
		5	0								28/1625							

TEST RUN NUMBERS

TYPE OF DATA

α OR β SCHEDULES

COEFFICIENT SCHEDULES

IDVAR (1) IDVAR (2) NDV

TABLE II. (Concluded)

TEST: OS-3 | TUNNEL: 8x7

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES P_t inHg			NO. OF RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 2.5	3.0	3.5
	ORBITER	6	0	30				29 / 1633	30 / 1642	31 / 1651
		10	0					29 / 1634	30 / 1643	31 / 1652
		14	0					29 / 1635	30 / 1644	31 / 1653
		18	0					29 / 1636	30 / 1645	31 / 1654
		6	3					29 / 1637	30 / 1646	31 / 1655
		10	3					29 / 1638	30 / 1647	31 / 1656
		14	3					29 / 1639	30 / 1648	31 / 1657
		18	3					29 / 1640	30 / 1649	31 / 1658
		10	6					29 / 1641	30 / 1650	31 / 1659

TEST RUN NUMBERS

TYPE OF DATA

α OR β SCHEDULES

COEFFICIENT SCHEDULES

IDVAR (1) IDVAR (2) NDV

TABLE III. MODEL DIMENSIONAL DATA

MODEL COMPONENT: BODY - (B_{18})

GENERAL DESCRIPTION: Fuselage, 2A Configuration, Lightweight Orbiter, per Rockwell lines VL70-000089 "B".

MODEL SCALE - 0.040

DRAWING NUMBER: VL70-000089 "B", VL70-000092, -93, -94 "A"

DIMENSIONS:	FULL SCALE	MODEL SCALE
Length - in.	1328.3	53.1320
Max Width - in. (@ X_o = 1528.3)	265.0	10.60
Max Depth - in. (@ X_o = 1480.52)	248.0	9.920
Fineness Ratio	5.012	5.012
Area - ft^2		
Max Cross-Sectional	456.4	0.73024

TABLE III. MODEL DIMENSIONAL DATA (Continued)

MODEL COMPONENT: CANOPY - (C_8)

GENERAL DESCRIPTION: 2A configurations per lines VL70-000092.

MODEL SCALE: 0.040

DRAWING NUMBER: VL70-000092

DIMENSIONS:	FULL SCALE	MODEL SCALE
Length (Sta Fwd Bulkhead)	391.0	15.640
Max Width (T.E. Bulkhead)	560.0	22.40

TABLE III. MODEL DIMENSIONAL DATA (Continued)

MODEL COMPONENT: **BODY FLAP - (F_4)**

GENERAL DESCRIPTION: **2A configuration per NR lines VL70-0000940.**

MODEL SCALE: 0.040

DRAWING NUMBER: **VL70-000094A**

DIMENSIONS:	FULL SCALE	MODEL SCALE
Length	84.70	3.3880
Max Width	265.00	10.60
Area - ft^2		
Max Cross-Sectional		
Planform	142.64	0.22822
Wetted		
Base	38.65	0.06184

TABLE III. MODEL DIMENSIONAL DATA (Continued)

MODEL COMPONENT: OMS POD - (M_5)

GENERAL DESCRIPTION: 2A lightweight configuration per NR lines VL70-000094A.

MODEL SCALE: 0.040

DRAWING NUMBER: VL70-000094A

DIMENSIONS:	FULL SCALE	MODEL SCALE
Length	346.0	13.840
Max Width	108.0	4.320
Max Depth	113.0	4.520

TABLE III. MODEL DIMENSIONAL DATA (Continued)

MODEL COMPONENT: VERTICAL - (V_7) Lightweight orbiter configuration

GENERAL DESCRIPTION: Centerline vertical tail, double-wedge airfoil with rounded leading edge.

MODEL SCALE: 0.040

DRAWING NUMBER: VL70-000139, VL70-000095

DIMENSIONS:	FULL SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.), ft^2 Planform	452.92	0.68147
Span (Theo.), in.	315.72	12.62880
Aspect Ratio	1.675	1.675
Rate of Taper	0.507	0.507
Taper Ratio	.404	.404
Sweep Back Angles, degrees		
Leading Edge	45.000	45.000
Trailing Edge	26.249	26.249
0.25 Element Line	41.130	41.130
Chords:		
Root (Theo.) WP	268.50	10.740
Tip (Theo.) WP	108.47	4.33880
MAC	199.81	7.99240
Fus. Sta. of .25 MAC	1463.50	58.540
W.P. of .25 MAC	635.522	25.42088
B.L. of .25 MAC	0.00	0.00
Airfoil Section		
Leading Wedge Angle, deg.	10.000	10.000
Trailing Wedge Angle, deg.	14.920	14.920
Leading Edge Radius	2.00	0.080
Void Area	13.17	0.02107
Blanketed Area	0.0	0.0

TABLE III. MODEL DIMENSIONAL DATA (Continued)

MODEL COMPONENT: WING - (W_{108}) New lightweight orbiter

GENERAL DESCRIPTION: Orbiter configuration per lines VL70-000093. NOTE: Dihedral angle is defined at the lower surface of the wing at the 75.33 percent element line projected into a plane perpendicular to the FPL.

MODEL SCALE: 0.040 DRAWING NO.: VL70-000093

DIMENSIONS:	FULL SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.), ft^2		
Planform	2690.00	4.3040
Span (Theo.), in.	936.68	37.46720
Aspect Ratio	2.265	2.265
Rate of Taper	1.177	1.177
Taper Ratio	0.200	0.200
Dihedral Angle, degrees	3.500	3.500
Incidence Angle, degrees	3.000	3.000
Aerodynamic Twist, degrees	0.00	0.00
Sweep Back Angles, degrees		
Leading Edge	45.000	45.000
Trailing Edge	-10.24	-10.24
0.25 Element Line	35.209	35.209
Chords:		
Root (Theo.) B.P.0.0.	689.24	27.56960
Tip, (Theo.) B.P.	137.85	5.5140
MAC	474.81	18.99240
Fus. Sta. of .25 MAC	1136.89	45.47560
W.P. of .25 MAC	299.20	11.9680
B.L. of .25 MAC	182.13	7.28520
EXPOSED DATA		
Area (Theo.), ft^2	1752.29	2.80366
Span, (Theo.), in. BP108	720.68	28.82720
Aspect Ratio	2.058	2.058
Taper Ratio	0.2451	0.2451
Chords		
Root BP108	562.40	22.4960
Tip 1.00 b/2	137.85	5.5140
MAC	393.03	15.72120
Fus. Sta. of .25 MAC	1185.31	47.41240
W.P. of .25 MAC	300.20	12.0080
B.L. of .25 MAC	143.76	5.75040
Airfoil Section (Rockwell Mod NASA) XXXX-64		
Root b/2 =	0.10	0.10
Tip b/2 =	0.12	0.12
Data for (1) of (2) Sides		
Leading Edge Cuff		
Planform Area, ft^2	120.33	0.19253
Leading Edge Intersects Fus M.L. @ Sta	560.0	22.40
Leading Edge Intersects Wing @ Sta	1035.0	41.40

TABLE III. MODEL DIMENSIONAL DATA (Continued)

MODEL COMPONENT: SOLID ROCKET BOOSTER - (S_6)

GENERAL DESCRIPTION: 2A configuration per Rockwell lines: VL77-000012 "B" and VL72-000061 "C" body of revolution; data for (1) of (2) sides.

MODEL SCALE: 0.040

DRAWING NUMBER: VL77-000012 "B"

DIMENSIONS:	FULL SCALE	MODEL SCALE
Length - in. (includes nozzle)	1741.0	69.640
Max Width (dia.) in. BSRM tank	142.0	5.680
Max (dia.) aft skirt	259.0	10.360
Fineness Ratio L/D	6.722	6.722
Area - ft^2		
Max Cross-Sectional	365.87	0.58539

TABLE III. MODEL DIMENSIONAL DATA (Concluded)

MODEL COMPONENT: **EXTERNAL TANK-(T_{10})**

GENERAL DESCRIPTION: External oxygen hydrogen tank, 3 configuration, per Rockwell lines VL78-000041 and VL72-000088.

MODEL SCALE: 0.040

DRAWING NUMBER: VL72-000088, VL78-000041

DIMENSIONS:	FULL SCALE	MODEL SCALE
Length - in. (nose @ X_T = 309)	1865	74.60
Max Width (dia.) - in.	324	12.960
Max Depth	--	--
Fineness Ratio	5.75617	5.75617
Area - ft^2		
Max Cross-Sectional	572.555	0.91609
W.P. of tank centerline, (X_T) in.	400.0	16.00

TABLE IV. ORBITER INSTRUMENTATION

TRANSDUCER NO.	FULL SCALE			MODEL SCALE			REMARKS
	X_o	Y_o	Z_o	X_o	Y_o	Z_o	
1	260	0	--	10.40	0	--	Fus. Lower Surf. on ℄
2	330	0	--	13.20	0	--	
3	400	0	--	16.00	0	--	
4	500	75	--	20.00	3.00	--	
5	500	0	--	20.00	0	--	on ℄
6	500	-75	--	20.00	-3.00	--	
7	600	0	--	24.00	0	--	on ℄
8	1000	0	--	40.00	0	--	
9	1400	0	--	56.00	0	--	
10	300	0	--	12.00	0	--	Fus. Upper Surf. on ℄
11	390	0	--	15.60	0	--	
12	420	15	--	16.80	0.60	--	Left Center Window
13	500	0	--	20.00	0	--	Fus. Upper Surf. on ℄
14	600	60	--	24.00	2.40	--	
15	600	0	--	24.00	0	--	on ℄
16	1000	0	--	40.00	0	--	on ℄
17	1000	60	--	40.00	2.40	--	
18	1265	0	--	50.60	0	--	on ℄
19	1430	25	--	57.20	1.00	--	
20	460	55	--	18.40	2.20	--	Left Side Window
21	500	60	--	20.00	2.40	--	Fus. L.H. Side
22	660	60	--	26.40	2.40	--	
23	1200	60	--	48.00	2.40	--	
24	1400	--	460	56.00	--	18.40	OMS Pod Left Side
25	1530	--	480	61.20	--	19.20	
26	400	--	396	16.00	--	15.84	Fus. L.H. Side
27	500	--	396	20.00	--	15.84	
28	600	--	396	24.00	--	15.84	

TABLE IV. ORBITER INSTRUMENTATION (Concluded)

TRANSDUCER NO.	FULL SCALE			MODEL SCALE			REMARKS
	X_O	Y_O	Z_O	X_O	Y_O	Z_O	
29	1000	--	396	40.00	--	15.84	Fus. L.H. Side
30	1000	--	396	40.00	--	15.84	Fus. R.H. Side
31	1200	--	396	48.00	--	15.84	Fus. L.H. Side
32	1400	--	396	56.00	--	15.84	
33	400	--	330	16.00	--	13.20	
34	500	--	330	20.00	--	13.20	
35	800	--	335	32.00	--	13.40	
36	1000	--	345	40.00	--	13.80	
37	1200	--	335	48.00	--	13.40	
38	1400	--	310	56.00	--	12.40	
39	1000	150	--	40.00	6.00	--	Wing Upper Surf.
40	1000	150	--	40.00	6.00	--	Wing Lower Surf.
41	1200	150	--	48.00	6.00	--	Wing Upper Surf.
42	1200	150	--	48.00	6.00	--	Wing Lower Surf.
43	1350	150	--	54.00	6.00	--	Wing Upper Surf.
44	1350	150	--	54.00	6.00	--	Wing Lower Surf.
45	1200	250	--	48.00	10.00	--	Wing Upper Surf.
46	1200	250	--	48.00	10.00	--	Wing Lower Surf.
47	1350	250	--	54.00	10.00	--	Wing Upper Surf.
48	1350	250	--	54.00	10.00	--	Wing Lower Surf.
49	1350	350	--	54.00	14.00	--	Wing Upper Surf.
50	1450	--	600	58.00	--	24.00	Vertical Tail
51	1550	--	600	62.00	--	24.00	
52	1590	--	750	63.60	--	30.00	
53	600	--	325	24.00	--	13.00	Fus. L.H. Side
54	600	--	325	24.00	--	13.00	Fus. R.H. Side
55	1400	--	310	56.00	--	12.40	

TABLE V. EXTERNAL TANK INSTRUMENTATION

TRANSDUCER NO.	FULL SCALE			MODEL SCALE			ϕ	REMARKS
	X_T	Y_T	Z_T	X_T	Y_T	Z_T		
60	350	0	--	14.00	0	0	180	Top ℄
61	720	162	400	28.80	6.48	16.00	90	Left Side
62	830	162	400	33.20	6.48	16.00	90	
63	940	162	400	37.60	6.48	16.00	90	
64	1060	162	400	42.40	6.48	16.00	90	
65	940	114.6	514.6	37.60	4.58	20.58	135	
66	1060	114.6	514.6	42.40	4.58	20.58	135	
67	940	0	562	37.60	0	22.48	180	Top ℄
68	1060	0	562	42.40	0	22.48	180	
69	885	0	562	35.40	0	22.48	180	
70	885	114.6	514.6	35.40	4.58	20.58	135	Left Side
71	885	162	400	35.40	6.48	16.00	90	
72	1000	0	562	40.00	0	22.48	180	Top ℄
73	1000	114.6	514.6	40.00	4.58	20.58	135	Left Side
74	1000	162	400	40.00	6.48	16.00	90	
75	885	0	238	35.40	0	9.52	0	Bottom ℄
76	1060	0	238	42.40	0	9.52	0	
77	420	0	--	16.80	0	--	180	Top ℄
78	1600	162	400	64.00	6.48	16.00	90	Left Side
79	2050	114.6	514.6	82.00	4.58	20.58	135	

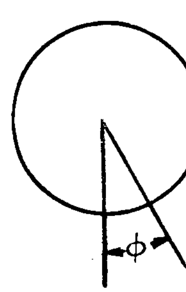
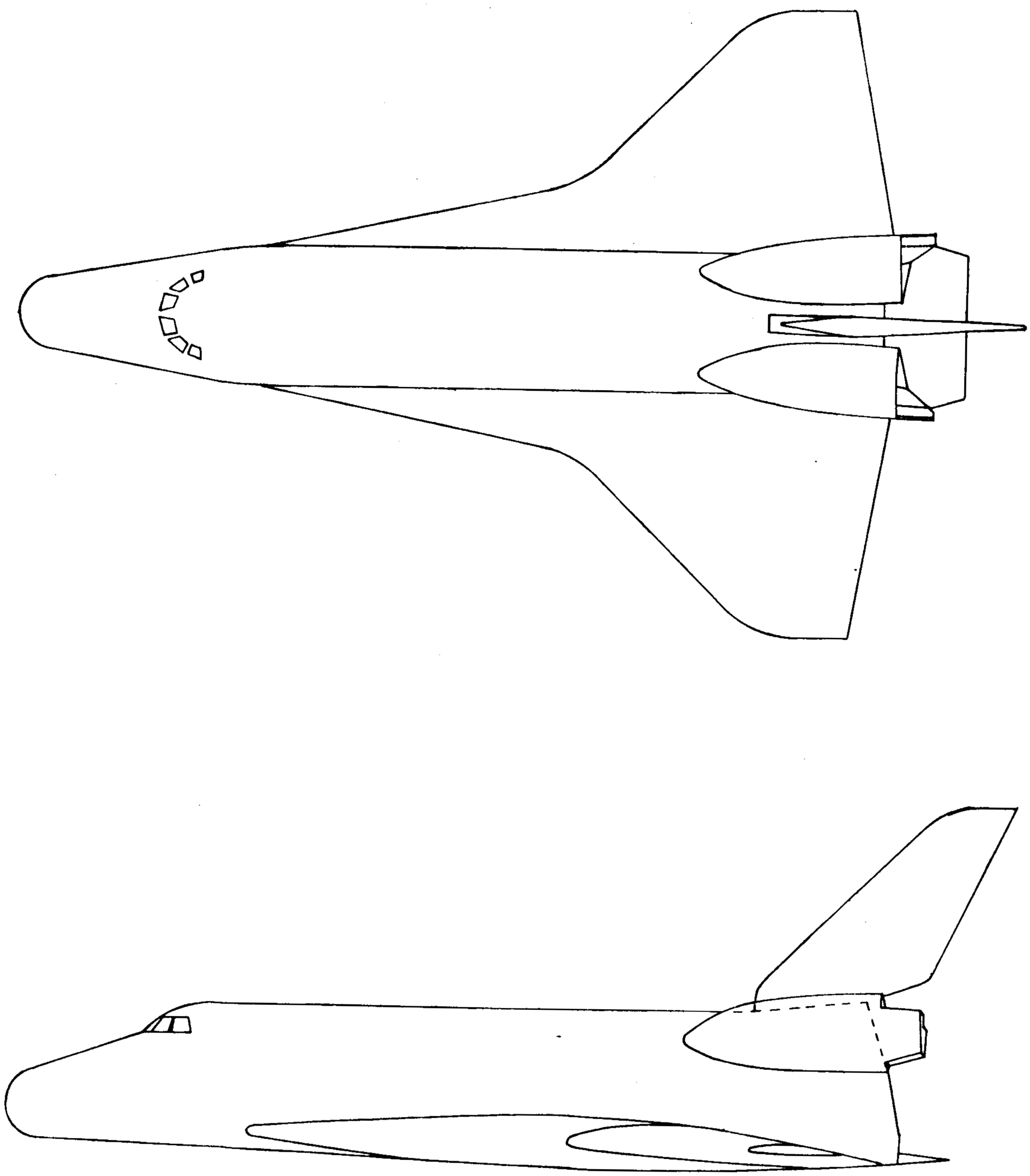


TABLE VI. SRB INSTRUMENTATION

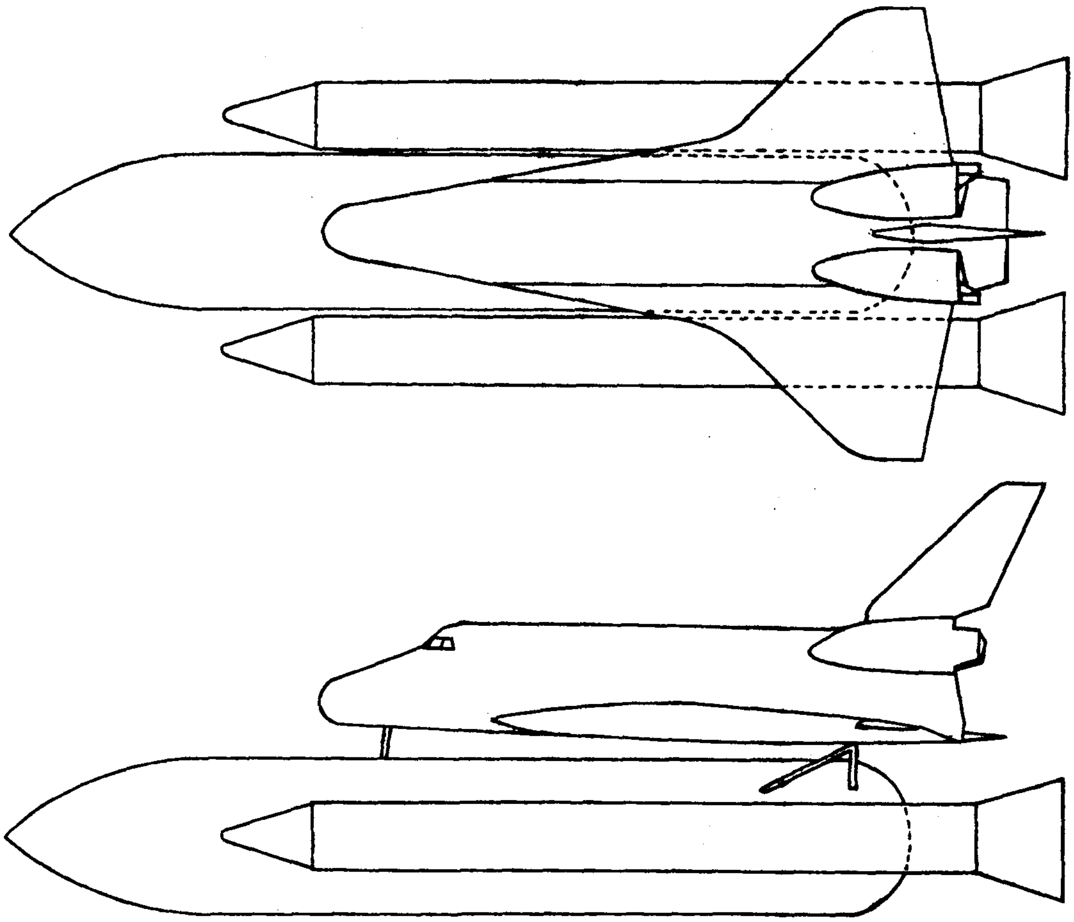
TRANSDUCER NO.	FULL SCALE			MODEL SCALE			ϕ	REMARKS
	X_s	Y_s	Z_s	X_s	Y_s	Z_s		
80	340	--	400	13.60	--	16.00	270	Inboard
81	400	0	329	16.00	0	13.16	0	Bottom ℄
82	475	0	329	19.00	0	13.16	0	
83	1760	-71	400	70.40	-2.84	16.00	270	Inboard
84	1830	--	400	73.20	--	16.00	270	
85	400	0	471	16.00	0	18.84	180	Top ℄
86	475	0	471	19.00	0	18.84	180	
87	1760	0	471	70.40	0	18.84	180	
88	1830	0	--	73.20	0	--	180	
89	1312	0	471	52.48	0	18.84	180	
90	1380	0	471	55.20	0	18.84	180	
91	1380	+71	400	55.20	2.84	16.00	90	Outboard

TABLE VII. FLIGHT DYNAMIC PRESSURE LOOKUP TABLE

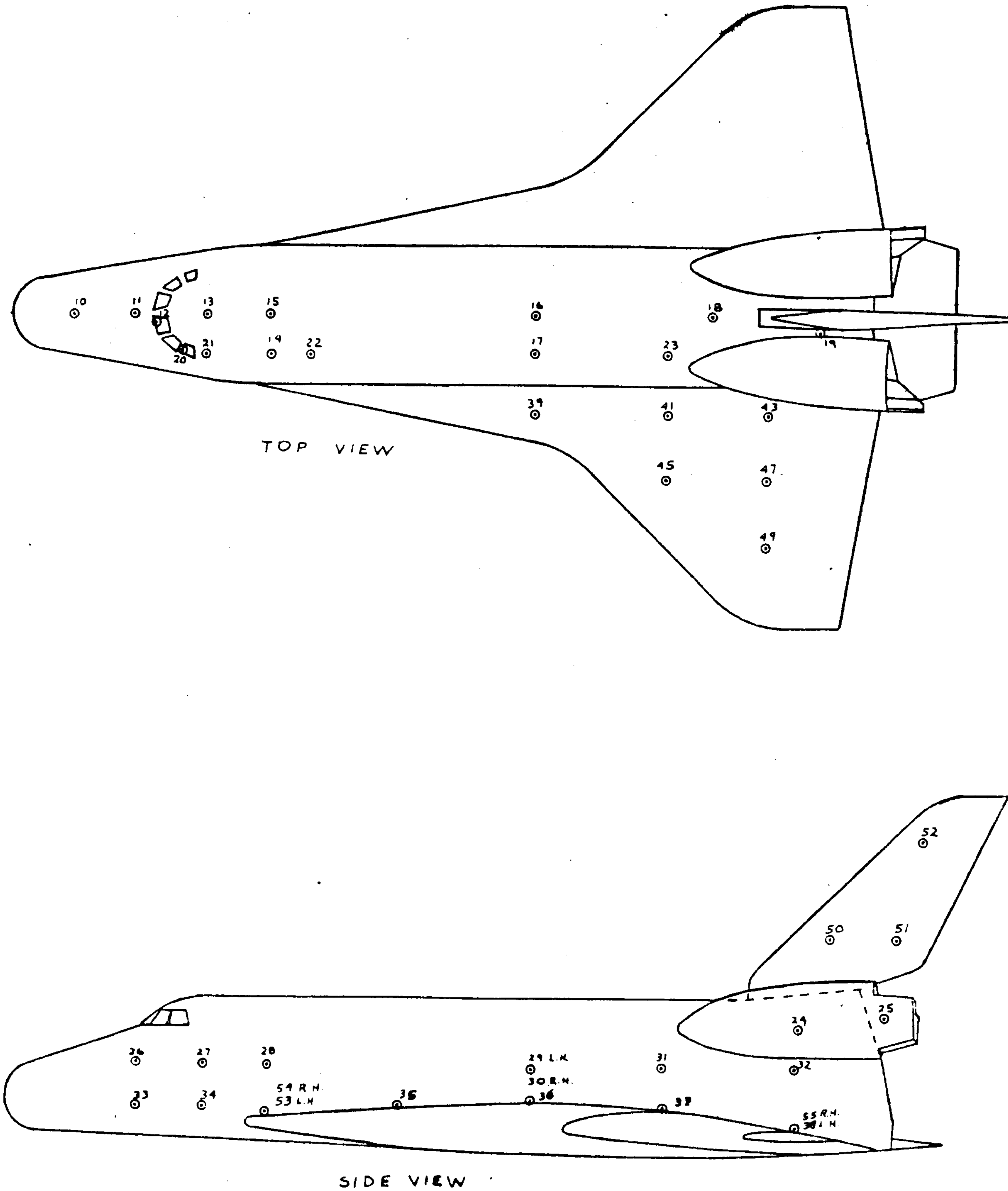
M_∞	q_{FLT}(PSF)	
0.50	310	
0.60	410	
0.70	505	
0.80	580	
0.90	620	
0.95	630	
1.00	640	11 x 11
1.05	645	
1.10	650	
1.15	655	
1.30	655	
1.40	650	
1.50	635	
1.60	620	
1.70	605	
1.80	580	9 x 7
2.00	540	
2.10	520	
2.20	495	
2.50	415	
2.50	255	
2.80	302	
3.00	316	8 x 7
3.20	321	
3.40	321	
3.50	320	



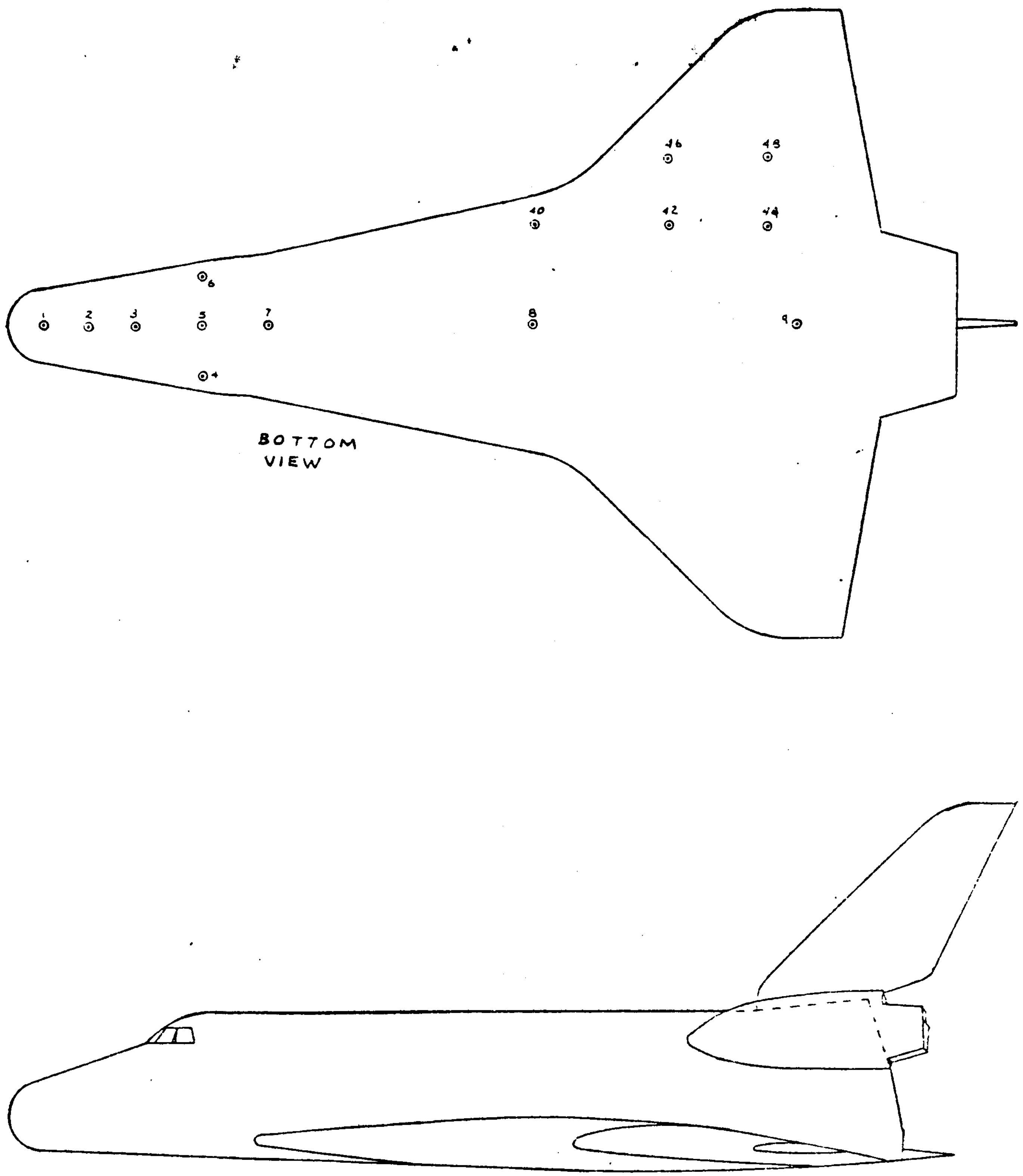
a. Orbiter
Figure 1. Model layout.



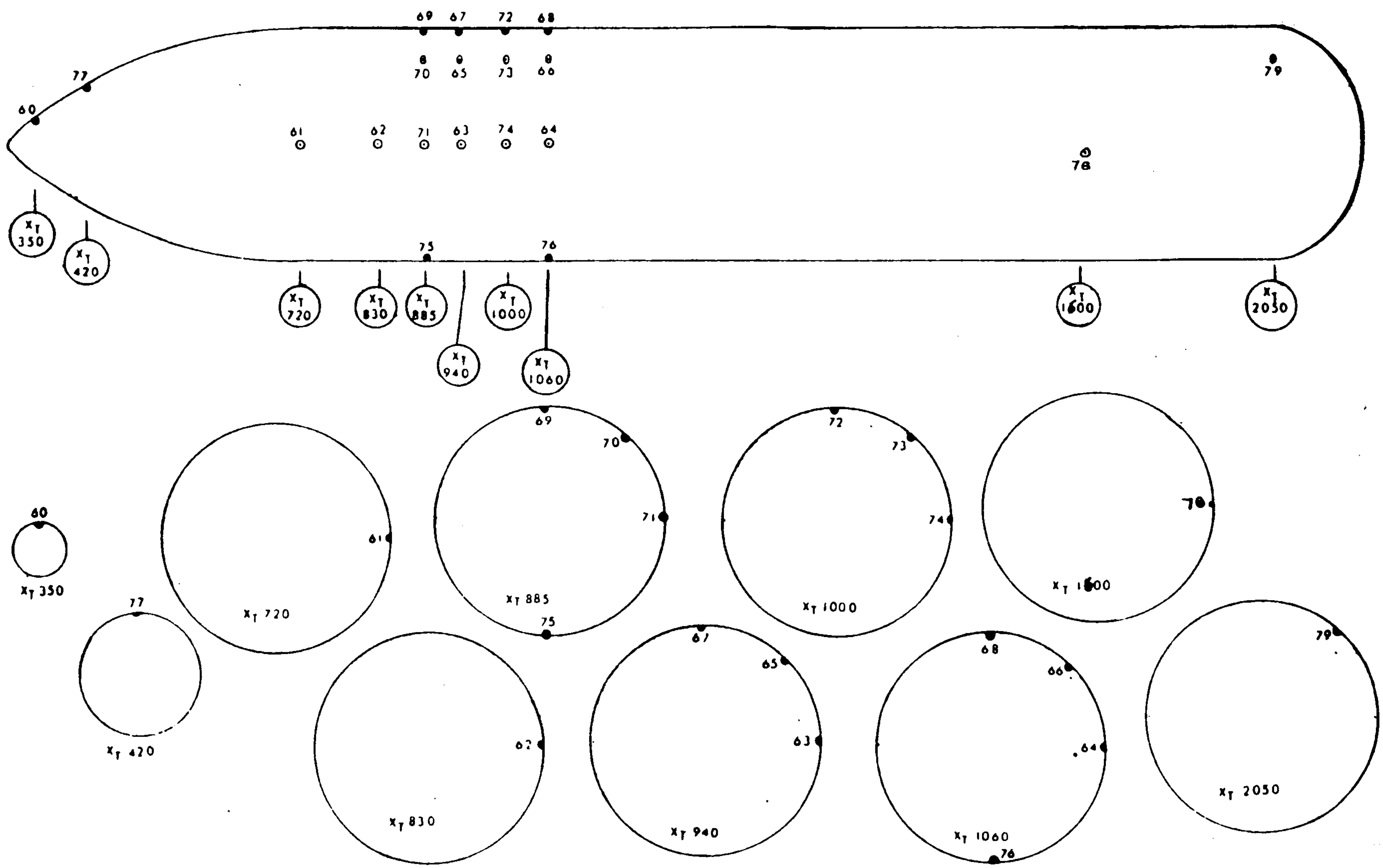
b. Integrated Vehicle
Figure 1. Concluded.



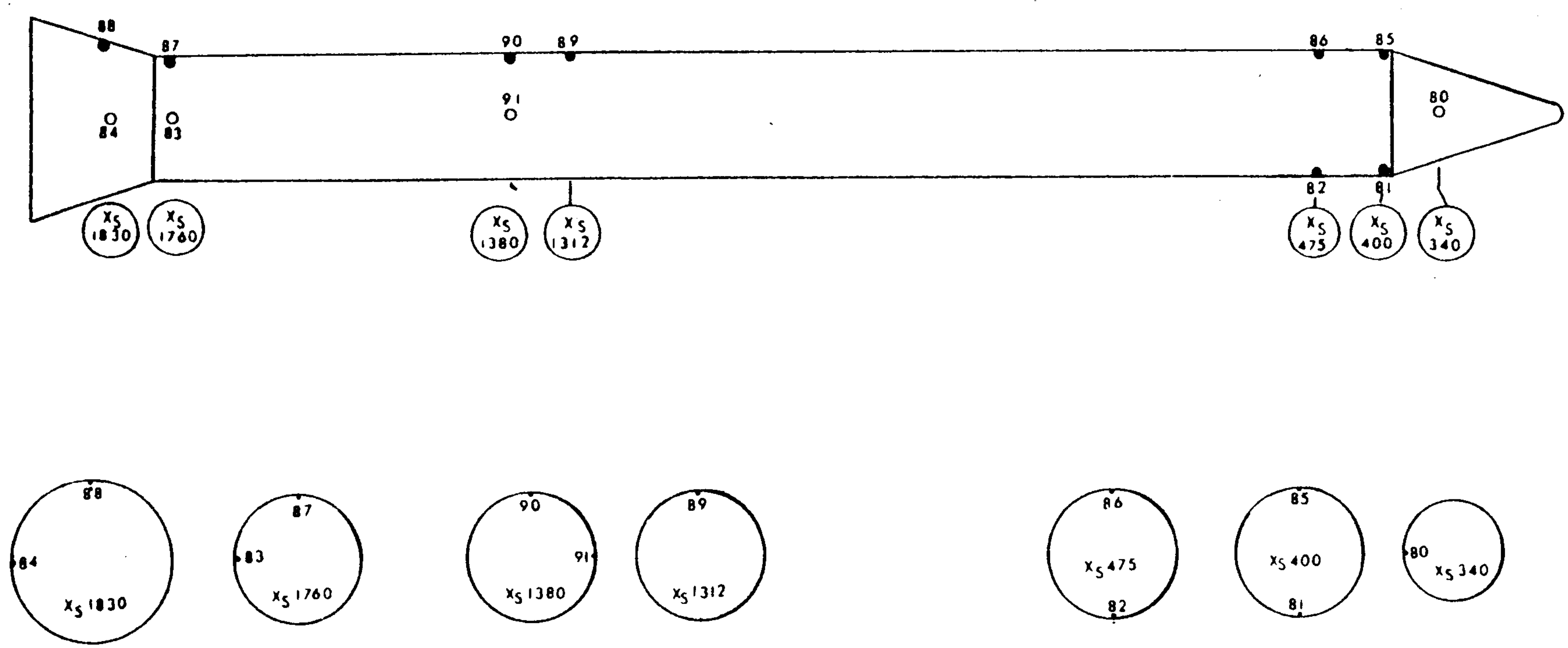
a. Orbiter Instrumentation - Top and Side View
Figure 2. Model sketches.



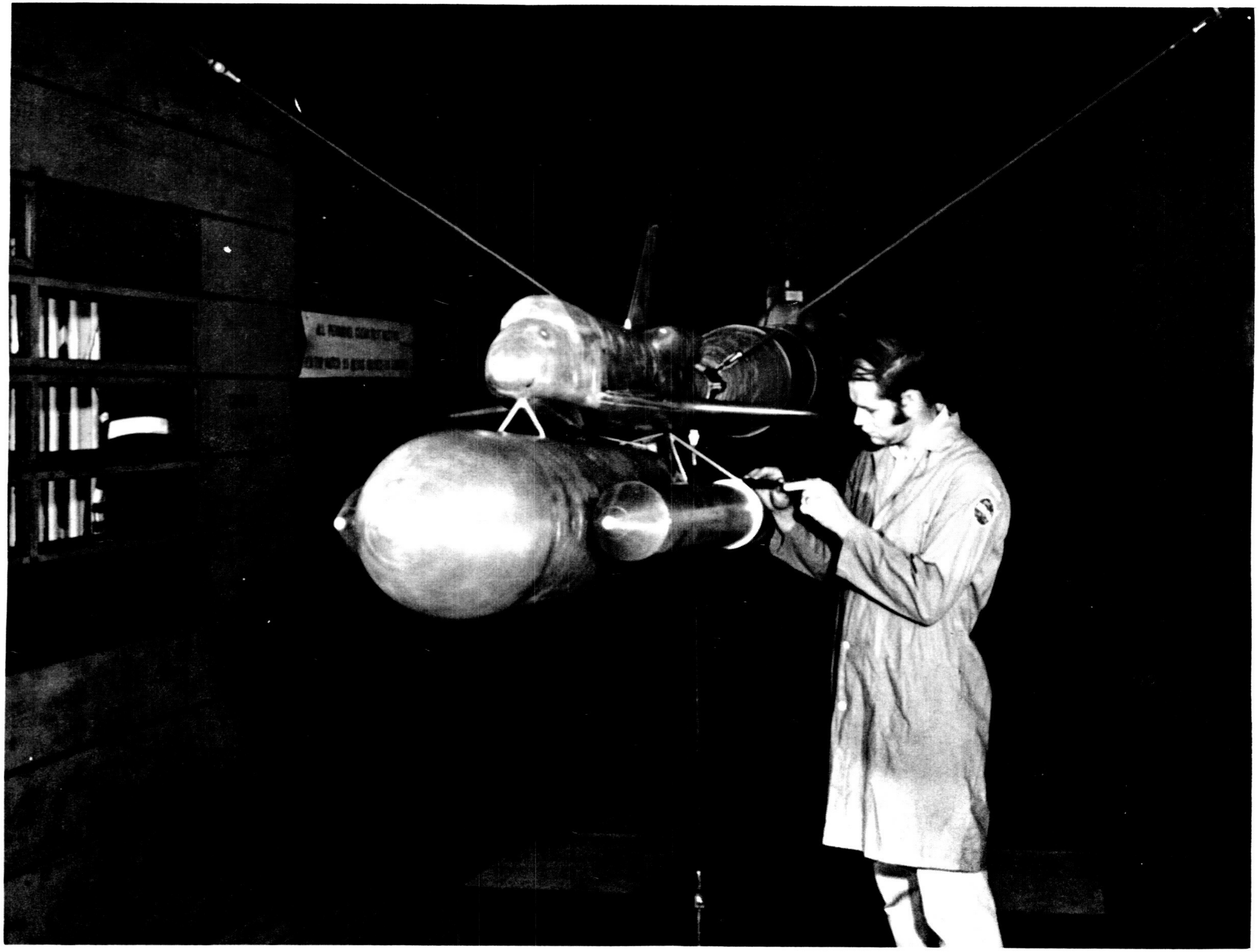
b. Orbiter Instrumentation - Bottom View
Figure 2. Continued.



c. ET Instrumentation
Figure 2. Continued.

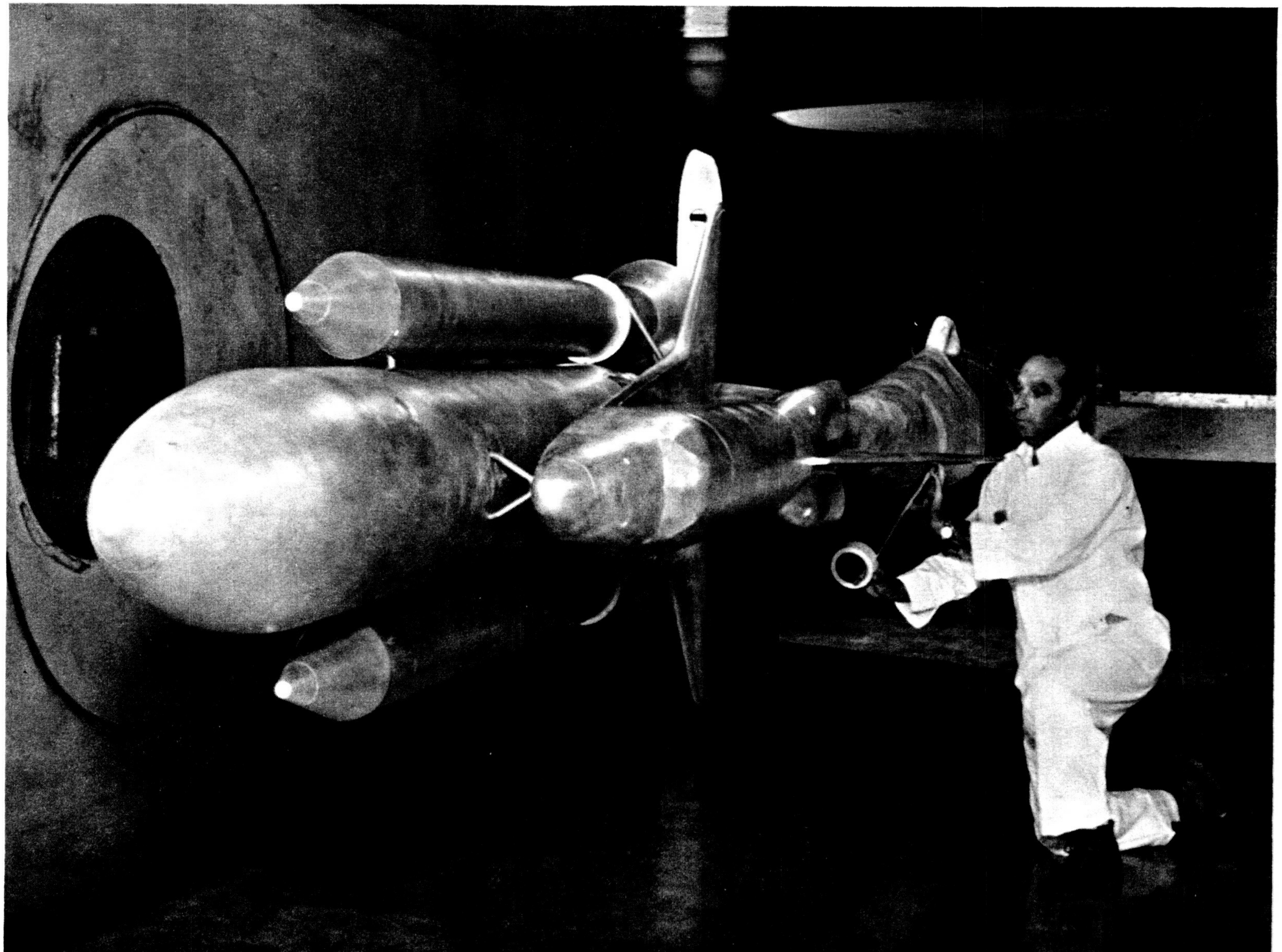


d. L. H. SRB Instrumentation
Figure 2. Concluded

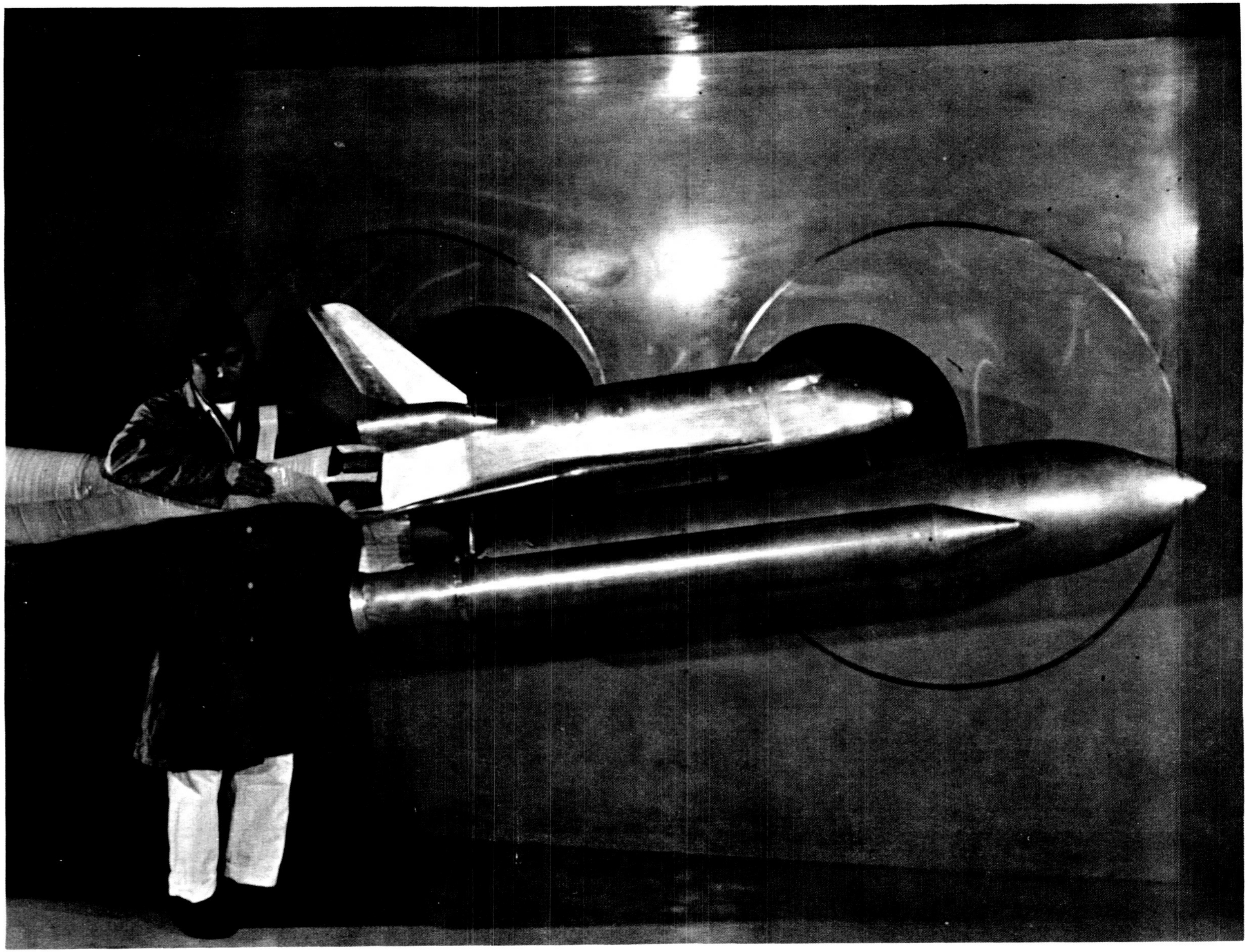


a. Installation ARC 11 x 11

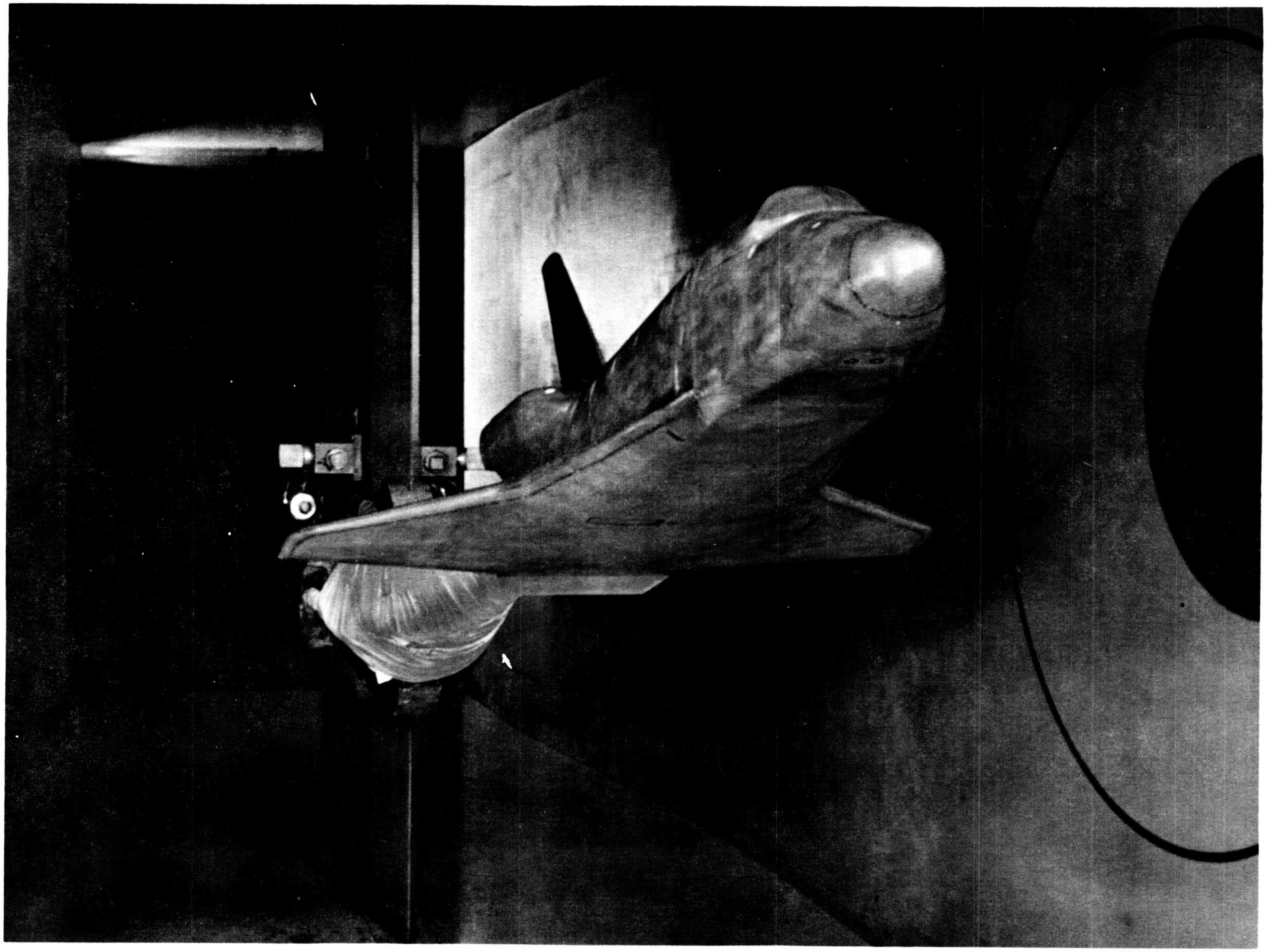
Figure 3. Model photographs.



b. Installation ARC 9 x 7
Figure 3. Continued.



c. Installation ARC 8 x 7
Figure 3. Continued.



d. Installation ARC 8 x 7
Figure 3. Concluded.